

FINAL REPORT

for the project

"Research on Habitat Manipulation and Management of Fender's Blue Butterfly Areas"

Prepared by

Mark V. Wilson

and

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Submitted to

**Oregon Field Office, The Nature Conservancy
Oregon Natural Heritage Program**

Contract No. ORFO-070994

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SUMMARY

We report first-year results from two field experiments evaluating the effectiveness of various techniques for the control of pest plants in Fender's blue butterfly habitat. In the woody-plant study, we monitored the effects of mowing, mowing and herbicides, and burning on woody plants and key native and non-native grasses and forbs. All treatments reduced woody plant cover, and no treatment significantly harmed populations of important native species. One year after manipulations, burning was the most effective overall treatment.

In the tall-oatgrass study, we monitored the effects of different mowing regimes on groups of native and non-native grasses and forbs. No regime caused a statistically significant decline in tall oatgrass, although mowing in early summer or late fall were particularly promising techniques at reducing non-native cover without diminishing native species. Removing cut material greatly reduced the effectiveness of mowing.

Burning in the woody-plant control study and certain mowing regimes in the tall-oatgrass control study performed well. As for the other treatments, nothing in these studies calls for halting the use of the pest-plant control techniques evaluated, except for the removal of cut material. On the other, the effectiveness of the techniques is still unclear, especially in promoting native species. Additional years of manipulations and monitoring should help resolve these issues.

INTRODUCTION

The problem

The rare Fender's blue butterfly (*Icaricia icarioides fenderi*) is found only in the Willamette Valley of Oregon (Hammond and Wilson, 1993). The low abundance of this butterfly makes it a high priority for conservation and management for recovery.

Native upland grasslands support the largest populations of this butterfly and its preferred host plant, Kincaid's lupine (*Lupinus sulphureus* ssp. *Kincaidii*). These remnant grasslands supply the butterfly with food plants, egg-laying sites, and proper flight conditions. The grasslands supply the lupine with essential light and nutrient resources and proper growing conditions. To a large extent, the recovery of the Fender's blue butterfly relies on the protection and restoration of these native grasslands (Wilson et al., 1992).

The native grasslands that support the Fender's blue butterfly are threatened by habitat destruction, succession, and pest plant dominance. Most habitat destruction in the past has been from urbanization and agricultural activities; these threats are also prominent today (Hammond and Wilson, 1993). Succession is a threat because the woody species that replace many of the early successional herbaceous plants do not provide the resources and conditions necessary for the Fender's blue butterfly and Kincaid's lupine. Fire suppression has allowed succession to woody plants to proceed at most sites. Pest plant dominance is a threat because these exotic plants suppress the native vegetation, including Kincaid's lupine and plants that supply nectar for Fender's blue butterfly adults. Tall oatgrass (*Arrhenatherum*) is one of the most important of these pest plants. The tall foliage of the pest plants shades many native species, and their extensive root systems can out compete native species for nutrients and water. The tall foliage of both pest herbaceous plants and woody plants also shades the flight paths of the Fender's blue butterfly, slowing its activities, which probably lowers its feeding and reproductive rates. For example, Fender's blue females will lay fewer eggs on Kincaid's lupine plants in the shade (P. C. Hammond, pers. comm.). Hammond and Wilson (1993) report that woody plant succession is a threat to 12 of 13 Fender's blue butterfly sites and aggressive weeds are a threat to 7 of 13 sites.

Potential management manipulations

Individuals concerned with protecting the Fender's blue butterfly agree that protecting and improving suitable habitat is a high priority for butterfly conservation. Yet little is known about how to apply control techniques or how effective they might be. Three control techniques widely applied in grassland management are prescribed burning, mowing, and herbicide application.

Burning is a favored management tool for many of the native grasslands in the Willamette Valley. A prime reason for the use of prescribed fire is its ability to slow or prevent the invasion of woody plants during natural succession (J. Beal, pers. comm.). Frequent fires are necessary to accomplish this goal, because trees allowed to grow for several years can survive grassland fires. A second motivation for the use of fire in management is the historical role of fire in the Willamette Valley (Johannessen et al., 1971; Towle, 1982; Boyd, 1986). Returning the natural disturbance process of fire is thought to aid in habitat restoration. Studies by K. Pendergrass (Connelly) have shown that prescribed fires can stimulate the growth of some native species (Connelly and Kauffman, 1991; Wilson et al., 1993). The effect of burning at different sites or on non-native species is still unclear (Wilson and Ingersoll, 1993; Macdonald, 1993).

Mowing, like burning, is widely used for vegetation management in the Willamette Valley. Few studies, however, document the success or failure of mowing in controlling pest plants. Often mowing is done without consideration of timing or height of mowing. Differences in both heights and life-history timing between many pest plants and native herbaceous species provide opportunities for improving the effectiveness of mowing as a control technique while reducing its impact on favored plants and animals.

Herbicide use has the twin advantage of relatively low expense and relatively high effectiveness. Herbicides are often applied once; control methods like fire and mowing often require repeated application to effect pest plant control.

The studies reported here were designed to evaluate the specific control techniques of burning, mowing, and herbicide application on some of the major pest plant species threatening Fender's blue butterfly. The objective of the first study was to evaluate prescribed fire, mowing, and herbicide use in reducing woody plant cover and promoting native species. The objective of the second study was to evaluate different mowing regimes in reducing tall oatgrass and promoting native species. These studies were initiated in 1994; this report presents results from a single year after experimental manipulations. Other studies have shown, however, that changes in vegetation might develop only several years after treatments are initiated.

Study areas

We conducted these studies within the Baskett Slough National Wildlife Refuge (Polk County, Oregon), which is administered by the U.S. Fish and Wildlife Service. The refuge contains several types of vegetation, including native grasslands dominated by the fescue *Festuca idahoensis* var. *roemerii*, disturbed grasslands dominated by non-native weeds and poison oak, and oak woodlands. Relatively large populations of the endangered Willamette daisy, *Erigeron decumbens* var. *decumbens*, and Kincaid's lupine, *Lupinus sulphureus* ssp.

Kincaidii, are also present. The Refuge harbors the largest remaining population of the Fender's blue butterfly.

The study area for the experiments on controlling woody plants was located to the southeast of the south peak of Baskett Butte, a promontory within the Baskett Slough National Wildlife Refuge. The grassland vegetation in this area is being invaded by the woody species *Rhus diversiloba*, *Rosa eglanteria*, *Rubus discolor* and *Crataegus* sp. We selected this area because of the abundance of invading woody plants, the presence of many native grasses and forbs, and the availability of enough area to conduct prescribed burns.

We conducted the experiment on controlling tall oatgrass at the saddle section south of Baskett Butte. We chose this area for several reasons. First, the area had an abundance of tall oatgrass, the subject of the study. Second, the native grasses *Festuca idahoensis* var. *roemeri* and *Danthonia californica* were present, allowing us to see the effects of control measures on key native plants. Third, *Lupinus sulphureus* ssp. *Kincaidii* (Kincaid's lupine) and *Icaricia icarioides fenderi* (Fender's blue butterfly) occurred just outside the study area, showing the area's potential as suitable habitat for these species of concern. Fourth, the vegetation was relatively homogeneous.

CONTROLLING WOODY PLANTS

Methods

Experimental design

We used a replicated before-after-control-intervention design, with five complete blocks. Each block (approximately 19 m x 20 m) was a section of the experimental area with a complete set of the following four treatments:

- Burn in October, 1994
- Mow in October, 1994
- Mow in October 1994, with herbicide applied to cut stems
- No manipulation

Mowing was accomplished with a tractor-driven rotary cutter, set to cut about 6 cm above the soil surface. We applied the herbicide glyphosate manually to the cut stems of woody plants with a wicking wand.

A buffer (0.5 - 1 m wide) was placed around each treatment area to reduce problems with edge effects. An additional mowed buffer (1 m) was placed around the burn treatment for safety.

Set-up procedures

Three permanent quadrats (1.0 m $\times$ 0.5 m) containing *Festuca* were randomly located within each of the treatment areas (60 quadrats, total). The diagonal corners of quadrats were marked with stakes labeled with the coordinates of the quadrat. Metal stakes were used in the burn treatment, small wooden stakes in the mow and mow with herbicide treatments, and wire flag stakes in the no manipulation treatment.

Areas with dense cover of shrubs surrounding the blocks were mowed May 9, 1994 to encourage new growth of vegetation that could help support a fire in the fall. Trees just outside the blocks were removed to improve fire safety.

Measurement procedure: treatment areas

Pre-manipulation data were collected June 3-14, 1994. We used the following phenological events to match manipulation sampling dates in subsequent years with the pre-manipulation sampling dates in 1994:

- *Calochortus tolmei* has completed blooming, but vegetative parts are still green
- *Dactylis glomerata* is in anthesis
- Flowers are appearing on *Agrostis diegoensis*
- *Lupinus* spp. are still flowering but past peak

Post-manipulation data were recorded June 7-12, 1995, at the same phenological time as in 1994.

The cover of shrubs and trees small enough to mow were measured within the entire treatment area by dividing each treatment area into four cells and estimating cover in each cell. Cover of the shrubs and trees was measured as a group and not by individual species. Species counted as shrubs were *Rhus diversiloba*, *Rosa eglanteria*, *Amelanchier alnifolia*, *Rubus discolor* and *Crataegus* sp. The same method for measuring cover of shrubs and small trees was used to measure the cover of *Lupinus sulphureus* ssp. *Kincaidii*, *Lupinus arbustus* and *Erigeron decumbens* var. *decumbens*.

In all estimates of cover, two investigators reached a consensus value, using calibrated templates as standards.

Measurement procedures: quadrats

The vegetative cover of each of the following species was measured in each quadrat:

- *Festuca idahoensis* var. *roemer*i, *Agrostis diegoensis*, *Danthonia californica*, and *Elymus glaucus* (native grasses)
- *Fragaria virginiana*, *Potentilla gracilis*, and *Calochortus tolmei* (native forbs)
- *Dactylis glomerata* and *Holcus lanatus* (non-native grasses)
- *Daucus carota*, *Vicia* spp., and *Plantago lanceolata* (non-native forbs).

These species were selected because as a group they account for most of the herbaceous cover and may also be important indicators of the ratio of native to non-native species in the community. In addition, we measured total herbaceous vegetative cover within quadrats.

After the pre-manipulation measurements were made, large trees (too big to mow, greater than 5 cm basal diameter) were removed by a fire crew in June. Three trees were removed from the burn treatment area within block E: *Acer macrophyllum*, *Pseudotsuga menziesii* and *Prunus* sp. One tree, *Malus* sp., was removed from the burn treatment area within block C. A clump of *Amelanchier alnifolia* and two *Quercus garryana* were removed from the burn treatment area within block B. The limbs and other woody debris were removed from the blocks and then chipped on site. At the same time, woody debris from the earlier mowing on May 9, 1994 was chipped.

Analysis

Treatment effects were calculated as proportional changes: the change in cover after the manipulation, divided by the initial cover. These effects were then tested using Friedman's nonparametric analysis of variance. The response variable for the Friedman test was thus
$$\frac{(Cover_{95} - Cover_{94})}{Cover_{94}}$$
. Positive values show increases in cover after the manipulation;

negative values show declines. This formula accounts for differences among areas in pre-manipulation cover. Proportional changes were calculated after cover data were transformed by adding 0.1, to avoid problems with zeroes in the denominator. The significance level (α) was set to 0.10, to reflect the exploratory nature of the study.

Results

Pre-manipulation community composition

Woody plants were a dominant component of the study site. Average cover of woody plants ranged between 13% and 35% within treatment areas (Table 1). *Rhus diversiloba* and *Rosa eglanteria* were the most common shrubs measured at the study site.

Certain measurement cells contained relatively high cover of Kincaid's lupine (up to 5%) and spur lupine (up to 13%). Since these lupines were abundant only along the northern sections of most blocks, their overall vegetative cover within treatment areas was low, ranging between 0.1% and 1.2% (Table 1). The Willamette daisy was present in low abundance.

The measured group of native herbaceous plant species had coverages averaging between 18% and 29% before manipulations (Table 2). *Danthonia* was the most abundant measured native grass species; *Fragaria* was the most abundant measured native forb species (Table 3).

The measured group of non-native herbaceous plant species had average coverages between 10% and 19% (Table 2). *Daucus* was the most abundant measured exotic plant species (Table 3).

Average overall herbaceous cover within quadrats ranged between 45% and 56% (Table 2). The 12 herbaceous species measured accounted for most (over two-thirds) of this cover.

Effects of experimental manipulations

All treatments dramatically decreased the cover of woody plants (Table 1). Burning and mowing+herbicide treatments caused the greatest reduction in woody cover. No individual rare species (Table 1) and only two measured herbaceous species (*Dactylis* and *Vicia*, Table 3) were significantly affected by treatments. Mowing caused a sharp increase in the cover of *Vicia* spp. compared with the moderate increases in control plots. Of the three treatments, however, burning had the most pronounced effect, with large increases in *Elymus* and large decreases in *Festuca* and *Dactylis*. These trends are reflected in statistically significant reductions by burning in the cover of the non-native grasses group, the overall non-native species group, and the group of all 12 measured species (Table 2).

Discussion

These management manipulations had the twin objectives of controlling pest plants and promoting native species. One year after treatment, several trends are promising. All treatments reduced woody plant cover, showing their effectiveness in pest plant control.

Because woody plants have a great capacity for regrowth, final conclusions must await observations from additional years.

Although no treatment significantly increased native species, neither did they reduce natives. That is, no treatment significantly reduced the cover of the rare lupines, the Willamette daisy, or native herbaceous species as a group. The burning treatment provided a bonus benefit of reducing non-native species, which might later translate into increased growth of the surviving native species.

CONTROLLING TALL OATGRASS

Methods

Experimental design

We used a replicated before-after-control-intervention approach with a randomized complete block design. Each of the four blocks was 8 m × 12 m, and contained 8 mowing treatments.

- Treatment 1 was mowing at 10 cm - 15 cm in late spring (May 27, 1994), when *Arrhenatherum elatius* is 30 cm - 50 cm tall.
- Treatment 2 was mowing at 10 cm - 15 cm in early summer (June 22, 1994), just before *Arrhenatherum elatius* matures seeds.
- Treatment 3 was mowing at 10 cm - 15 cm in early fall (September 15, 1994), the typical time for managers to mow.
- Treatment 4 was mowing at 10 cm - 15 cm in early spring (April 21, 1995), when *Arrhenatherum elatius* starts rapid growth.
- Treatment 5 was mowing at 10 cm - 15 cm in early summer (June 22, 1994), with removal of cut material.
- Treatment 6 was mowing at 50 cm in early summer (June 22, 1994). At this time, *Arrhenatherum elatius* is generally taller than 50 cm, while the native species are shorter.
- Treatment 7 was a double mowing at 10 cm - 15 cm in late spring (May 27, 1994) and the following early spring (April 21, 1995).
- Treatment 8 was a no-manipulation control.

Mowing treatments were applied with a hand-held rotary cutter. We regulated the height of cutting by placing several short stakes within each quadrat, with their tops at the proper cutting height.

Measurements

We collected pre-manipulation measurements May 23-27, 1994. We collected post-manipulation data May 17-30, 1995, when the community was at approximately the same phenological stage as during 1994 measurements. Measurements were recorded within two 1-m $\times$ 0.5-m quadrats inside the treatment area. Each measurement area had a 1-m buffer around it.

We measured within each quadrat the total cover of vascular plants and the cover of the non-native tall oatgrass, other non-native graminoids, the native grasses *Festuca* and *Danthonia*, non-native forbs, native forbs, and mosses.

In all estimates of cover, two investigators reached a consensus value, using calibrated templates as standards.

Analysis

Treatment effects were calculated as proportional differences: the change in cover after the manipulation, divided by the initial cover. These effects were then tested using Friedman's nonparametric analysis of variance. The response variable for the Friedman test was thus

$$\frac{(Cover_{95} - Cover_{94})}{Cover_{94}}. \text{ Positive values show increases in cover after the manipulation;}$$

negative values show declines. This formula accounts for differences among areas in pre-manipulation cover. Proportional changes were calculated after cover data were transformed by adding 0.1. to avoid problems with zeroes in the denominator. The significance level (α) was set to 0.10, to reflect the exploratory nature of the study.

We also developed an effectiveness index (EI) to show the overall effectiveness of treatments in meeting the design objectives. The index is the sum of the proportional *decline* in *Arrhenatherum* (Ar), the proportional *decline* in the group of other non-native species (NN), and the proportional *increase* in the group of native species (Nat). That is,

$$EI = \frac{Ar_{94} - Ar_{95}}{Ar_{94}} + \frac{NN_{94} - NN_{95}}{NN_{94}} + \frac{Nat_{95} - Nat_{94}}{Nat_{94}}.$$

Larger values of EI reflect a better aggregate performance.

Results and discussion

Pre-manipulation community composition

Sampling confirmed the impression that *Arrhenatherum* dominated the site in 1994 (Table 4). *Arrhenatherum* had 15%-28% cover, about one-third of the overall cover of vascular plants. The two native grasses present had less cover, with *Festuca* at 4%-17% and *Danthonia* at 7%-22%. The group of other non-native grasses was also abundant (12%-31%). Most of these species were annuals, including *Bromus rigidus* and *Taeniatherum caput-medusae*. Forbs were relatively rare in 1994.

1995 community composition

Unmanipulated controls changed considerably from 1994 to 1995 (treatment 8 in Table 4). The cover of *Arrhenatherum*, other non-native grasses, and *Danthonia* all declined by half or more. In contrast, the cover of non-native forbs increased 6-fold. A particularly important non-native forb in 1995 was the annual *Sherardia arvensis*.

Effects of experimental manipulations

The group of "other non-native grasses" responded in a statistically significant way to the treatments (Table 4). Compared to the controls, treatment 1 (mowing in late spring) and treatment 2 (mowing in early summer) caused greater declines in this group. Treatment 4 (mowing in early spring) led to *less* reduction in the cover of this group than seen in the controls.

The response of the native-forb group also varied by treatment (Table 4). Treatment 7 (double mowing) caused the largest increase in native forb cover. Treatments 1, 2, 4, and 6 also performed better than the controls.

All treatments (especially treatments 2 and 3) caused a decrease in *Arrhenatherum* greater than in the controls, and all treatments reduced *Danthonia* less than the decline in controls. Neither of these patterns was statistically significant.

After one year of manipulations, does any treatment emerge as best? Treatments differed considerably in their overall effectiveness (Friedman test of the effectiveness index, $P < 0.001$). Treatment 2 (mowing at 10 cm - 15 cm in early summer) had the best overall combination of promoting natives species and inhibiting *Arrhenatherum* and the other non-native species (as compared to changes in the controls) (Figure 1). Treatment 3 (mowing at 10 cm - 15 cm in early fall) and treatment 6 (mowing at 50 cm in early summer) were also significantly better than controls. Treatment 5 (mowing at 10 cm - 15 cm in early summer) performed the worst overall. The only difference between the best treatment (treatment 2) and the worst treatment (treatment 5) was the removal of cut materials. A likely cause for this

difference is the dominance of the "other non-native grasses" and "non-native forbs" groups by annual species: annuals depend on seedling establishment, which can be inhibited by litter accumulation. Thus, removing cut biomass could stimulate annuals. This intriguing pattern bears further study.

GENERAL DISCUSSION

Most treatment effects were statistically non-significant. Several factors could cause this lack of pattern. First, spatial variability within the sites was considerable, even though we chose the tall-oatgrass site in particular for its relative homogeneity. These differences between blocks make it difficult to detect treatment effects, even with our replicated before-after-control-intervention approach.

Year-to-year variability adds a second layer of change, masking treatment effects. The dramatic one-year increase in non-native forbs in the tall-oatgrass study shows the importance of recording data for more than a single year. Additional years of monitoring will show if this forb increase is temporary or permanent.

A third impediment to detecting significant changes is the slow pace of ecological systems. Perennial plants like *Arrhenatherum* usually have significant belowground stores, allowing them to rebound after a single disturbance like mowing. Several years of treatments will probably be necessary to achieve control of *Arrhenatherum*.

The comparison of before-manipulation and after-manipulation data improved the detection of patterns. For example, the cover of woody plants in the woody-plant control study did not differ significantly among treatments in 1995. This failure to see pattern in the after-manipulation data was caused by the largest declines occurring in the treatment plots that just by chance had the highest cover in 1994. The before-after-control-intervention approach easily detected this significant and important effect of treatments on woody plants.

False conclusions are also more likely with conventional analyses. For example, treatment areas in the woody-plant study differed significantly in their cover of *Fragaria* in 1995 ($P < 0.01$), with mowed areas having less than one-third of the *Fragaria* cover of controls. But this pattern is due entirely to pre-existing variability in *Fragaria* cover: even before manipulations, *Fragaria* was least abundant in the area to be mowed. The before-after-control-intervention approach showed correctly that mowing had little effect on *Fragaria*.

Burning in the woody-plant control study and certain mowing regimes in the tall-oatgrass control study performed well. As for the other treatments, nothing in these studies calls for halting the use of the pest-plant control techniques evaluated. That is, no manipulation had dire effects on important native species. Managers of other Willamette Valley native prairies should feel comfortable continuing their use. (The one exception is removing cut material

from sites that, like our tall-oatgrass site, have heavy litter accumulation and annual plants present as seeds.) The overall effectiveness of the techniques is still unclear, however, especially in promoting native species. The responses of the perennial natives, which are of prime concern at the study sites, often takes several seasons to develop. Only repeated treatments and continued careful monitoring will demonstrate conclusively the value of these management approaches.

REFERENCES

Boyd, R. 1986. Strategies of Indian burning in the Willamette Valley. *Canadian Journal of Anthropology* 5:65-86.

Connelly, K. P., and J. B. Kauffman. 1991. Ecological effects of fire in Willamette Valley wetland prairies with species emphasis on *Lomatium bradshawii* and *Erigeron decumbens*, two rare endemic plants. Report to the U.S. Army Corps of Engineers. 45 pages.

Hammond, P. C., and M. V. Wilson. 1993. Status of the Fender's blue butterfly. Report to the U.S. Fish and Wildlife Service, 66 pages.

Johannessen, C. L., W. A. Davenport, A. Millet, and S. McWilliams. 1971. The vegetation of the Willamette Valley. *Ann. Ass. Am. Geogr.* 61:286-302.

Macdonald, C. 1993. Fire effects on a *Stipa lemmonii*-*Rhacomitrium canescens* grassland community. Final report for Katharine Ordway Stewardship Endowment Grants, The Nature Conservancy.

Towle, J. C. 1982. Changing geography of Willamette Valley woodlands. *Oregon Historical Quarterly* 83:66-87.

Wilson, M. V., K. P. Connelly, and L. E. Lantz. 1993. Plant species, habitat, and site information for Fern Ridge Reservoir. Report to Waterways Experiment Station, Corps of Engineers. 80 pages.

Wilson, M. V., P. C. Hammond, and J. B. Kauffman. 1992. The value of restoration and management in protecting biodiversity. *Northwest Environmental Journal* 8:201-202.

Wilson, M. V., and C. A. Ingersoll. 1993. Management guidelines and recommendations for Fern Ridge Reservoir. Report to Waterways Experiment Station, Corps of Engineers. 50 pages.

Table 1. Results from the woody-plant-control study: average cover (%) of woody plants, Kincaid's lupine, spur lupine, and Willamette daisy within treatment areas. "Before" refers to cover values recorded in 1994, before manipulations; "after" refers to cover values recorded in 1995, after manipulations. *P* are the probabilities that before-after changes differed significantly among treatments just by chance; treatments sharing letters were statistically indistinguishable.

	Year	Treatments				<i>P</i>
		Mow	Mow + Herbicide	Burn	Control	
Woody plants	Before	13.5	18.1	35.4	24.1	
	After	6.8b	6.3a	12.3a	22.8c	<.025
Kincaid's lupine	Before	0.5	0.4	0.2	0.2	
	After	0.4	0.4	0.2	0.1	ns
Spur lupine	Before	0.5	0.1	1.2	0.1	
	After	0.3	0.1	0.6	0.1	ns
Willamette daisy	Before	0.2	0.0	0.0	0.0	
	After	0.2	0.0	0.1	0.1	ns

Table 2. Results from the woody-plant-control study: average total and average cover (%) of groups of measured native and non-native grasses and forbs. (Values pertain only to the permanent quadrats and not necessarily to the treatment areas as a whole.) "Before" refers to cover values recorded in 1994, before manipulations; "after" refers to cover values recorded in 1995, after manipulations. *P* are the probabilities that before-after changes differed significantly among treatments just by chance; treatments sharing letters were statistically indistinguishable.

	Year	Treatments				<i>P</i>
		Mow	Mow + Herbicide	Burn	Control	
Total cover (all vascular plants)	Before	51.7	44.9	55.6	50.9	ns
	After	50.7	39.6	43.2	46.1	
Measured native grass species	Before	15.6	12.8	12.5	18.9	ns
	After	14.8	11.4	10.4	14.6	
Measured native forb species	Before	4.1	5.7	7.1	9.8	ns
	After	3.4	5.5	7.2	9.5	
Sum of measured natives	Before	19.7	18.5	19.6	28.7	ns
	After	18.2	16.9	17.6	24.1	
Measured non-native grass species	Before	4.0	1.1	7.5	1.7	<.05
	After	3.5b	0.7b	2.7a	1.8b	
Measured non-native forb species	Before	11.1	10.5	11.5	8.5	ns
	After	11.8	9.9	7.9	8.9	
Sum of measured non-native species	Before	15.1	11.6	18.9	10.2	<.01
	After	15.4b	10.7b	10.6a	10.7b	
All 12 measured species	Before	34.7	30.1	38.5	38.9	<.10
	After	33.6b	27.6b	28.2a	34.8b	

Table 3. Results from the woody-plant-control study: average cover (%) of common herbaceous plants within treated quadrats. "Before" refers to cover values recorded in 1994, before manipulations; "after" refers to cover values recorded in 1995, after manipulations. N = native, NN = non-native, G = grass, F = forb. *P* are the probabilities that before-after changes differed significantly among treatments just by chance; treatments sharing letters were statistically indistinguishable.

	Year	Treatments				<i>P</i>
		Mow	Mow + Herbicide	Burn	Control	
<i>Agrostis diegoensis</i> (NG)	Before	4.1	3.2	3.3	6.5	
	After	4.2	3.4	4.8	4.9	ns
<i>Danthonia californica</i> (NG)	Before	6.4	5.5	3.9	6.5	
	After	6.4	4.8	1.8	6.5	ns
<i>Elymus glaucus</i> (NG)	Before	1.7	0.5	0.9	2.9	
	After	2.5	1.2	2.1	1.7	ns
<i>Festuca idahoensis</i> var. <i>roemerii</i> (NG)	Before	3.4	3.6	4.5	3.0	
	After	1.7	2.1	1.7	1.6	ns
<i>Calochortus tolmei</i> (NF)	Before	0.7	1.2	0.5	0.8	
	After	0.5	1.1	0.7	0.6	ns
<i>Fragaria virginiana</i> (NF)	Before	2.9	4.1	6.1	8.8	
	After	2.4	4.0	6.1	8.5	ns
<i>Potentilla gracilis</i> (NF)	Before	0.5	0.5	0.4	0.2	
	After	0.6	0.4	0.4	0.5	ns
<i>Dactylis glomerata</i> (NNG)	Before	3.2	0.5	6.7	1.0	
	After	3.1b	0.3b	1.7a	1.0b	<.05
<i>Holcus lanatus</i> (NNG)	Before	0.8	0.5	0.8	0.7	
	After	0.4	0.4	1.0	0.8	ns
<i>Daucus carota</i> (NNF)	Before	7.5	6.2	6.8	5.7	
	After	7.3	6.0	4.8	5.7	ns
<i>Plantago lanceolata</i> (NNF)	Before	3.4	4.2	4.1	2.4	
	After	2.7	2.6	2.0	1.2	ns
<i>Vicia</i> spp. (NNF)	Before	0.1	0.1	0.6	0.4	
	After	1.9c	1.3bc	1.1a	2.1b	<.10

Table 4. Results from the tall-oatgrass study: average cover (%) of groups of native and non-native grasses and forbs. (See text for explanation of treatments.) "Before" refers to cover values recorded in 1994, before manipulations; "after" refers to cover values recorded in 1995, after manipulations. *P* are the probabilities that before-after changes differed significantly among treatments just by chance (+ : $P < 0.10$); treatments sharing letters were statistically indistinguishable.

	Year	Treatments								<i>P</i>
		1	2	3	4	5	6	7	8	
Total cover of vascular plants	Before	58.5	61.5	57.4	66.8	61.3	59.8	55.4	59.4	
	After	45.1	43.8	37.0	45.0	53.4	43.3	39.4	41.3	ns
<i>Arrhenatherum elatius</i>	Before	20.8	13.9	19.4	32.8	24.8	19.5	26.5	20.4	
	After	7.3	4.3	6.0	13.9	12.6	6.5	10.6	10.8	ns
Other non-native grasses	Before	23.3	24.9	26.0	17.3	11.4	16.6	14.8	24.8	
	After	9.0 _a	9.6 _a	13.5 _{ab}	11.4 _d	7.1 _{cd}	10.3 _{bc}	10.6 _{cd}	13.0 _{bc}	+
<i>Festuca idahoensis</i> var. <i>roemerii</i>	Before	4.8	7.6	4.9	8.1	15.5	20.1	5.6	1.4	
	After	3.9	5.0	3.6	3.3	6.4	12.0	1.9	1.5	ns
<i>Danthonia californica</i>	Before	15.0	19.4	12.6	11.6	11.6	7.8	10.5	18.9	
	After	6.1	13.0	7.5	4.9	9.4	4.8	6.5	8.4	ns
Non-native forbs	Before	3.5	4.8	3.0	4.4	3.5	3.5	5.5	3.1	
	After	25.5	18.0	15.6	18.0	27.9	17.8	18.6	15.8	ns
Native forbs	Before	0.5	0.5	0.0	0.1	2.1	0.1	0.0	0.4	
	After	0.8 _c	1.1 _c	0.0	0.5 _c	0.5 _{ab}	0.4 _{bc}	0.8 _d	0.0 _a	+
Moss	Before	18.4	36.9	27.3	6.9	17.1	21.1	13.9	7.9	
	After	33.5	40.9	39.3	12.8	20.4	27.9	18.5	14.1	ns

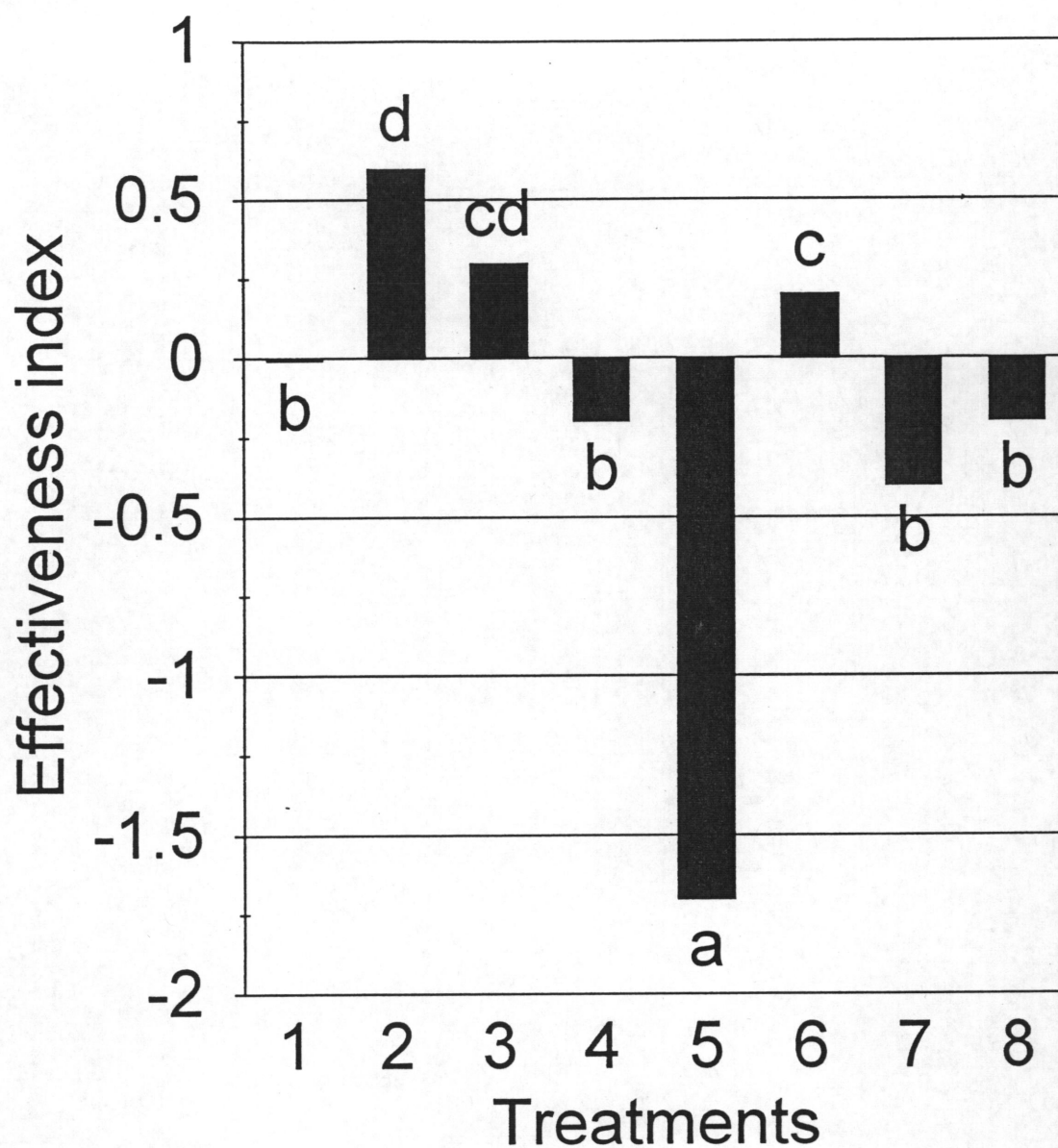


Figure 1. Results from the tall-oatgrass study: effectiveness index (EI). (See text for explanations of the index and treatments.) Treatments in general had a significant effect on EI. Individual treatments sharing letters were statistically indistinguishable.

